

Thermal Modeling Method Improvements for SAGE III on ISS



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- **Summary**

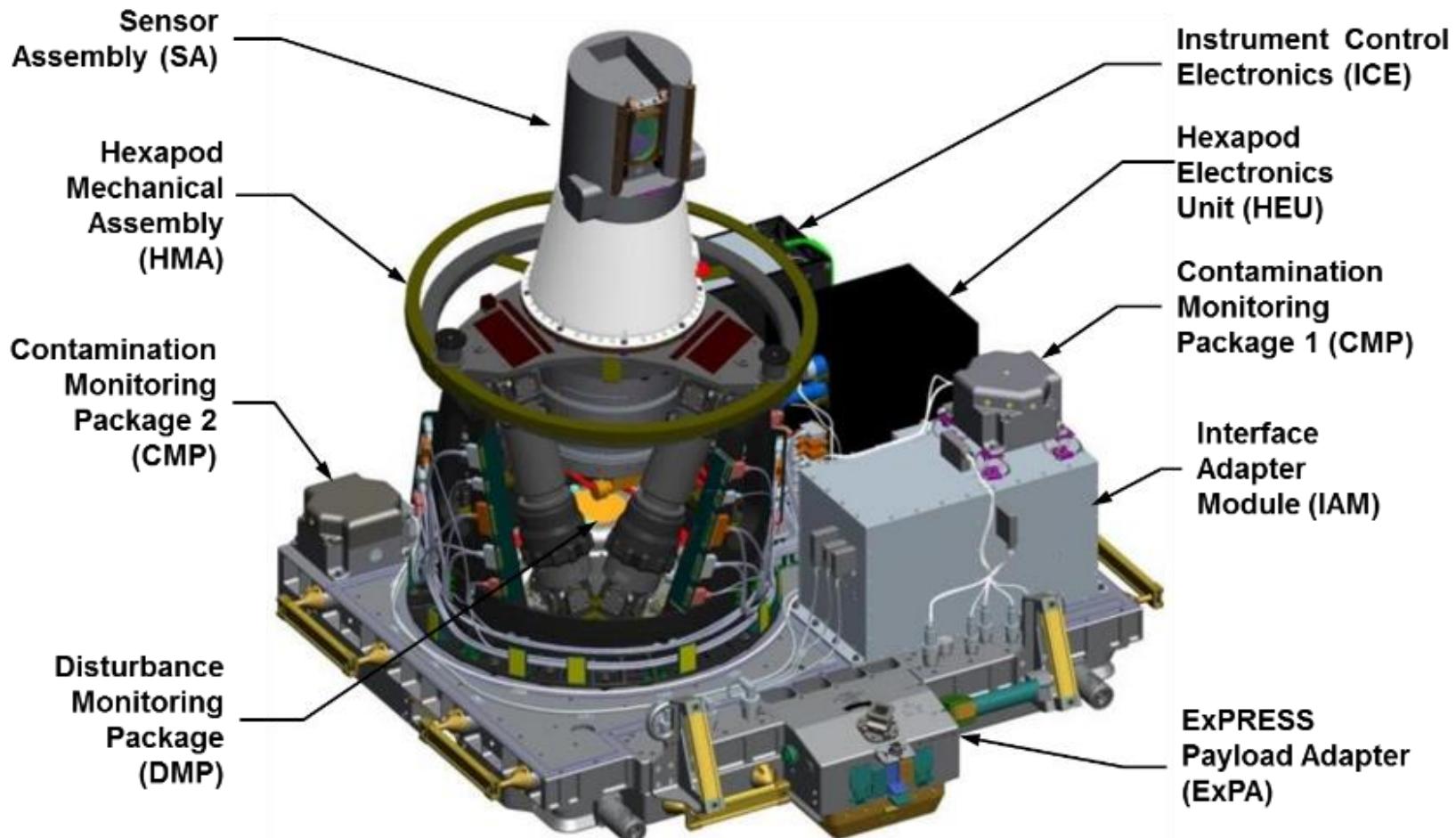


SAGE III on ISS Background

- SAGE III is an ISS-mounted science payload, to be launched on Falcon vehicle/Dragon capsule in 2016
- Three year minimum lifetime on ISS
- Monitors aerosols and other gases in stratosphere
- Thermal analyses are being completed for launch vehicle and all ISS scenarios
- Instrument Payload (IP) mounted on Nadir Viewing Platform (NVP)
- Several subsystems built in 1990's and placed in storage
 - Text legacy thermal models



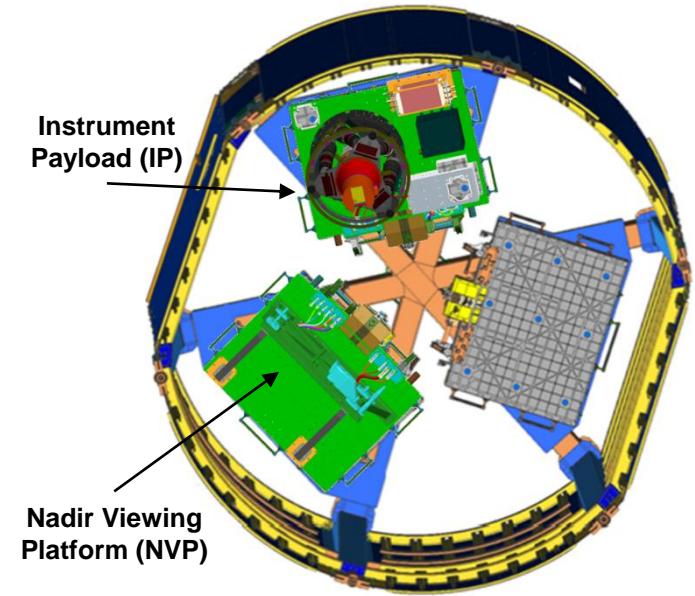
Instrument Payload



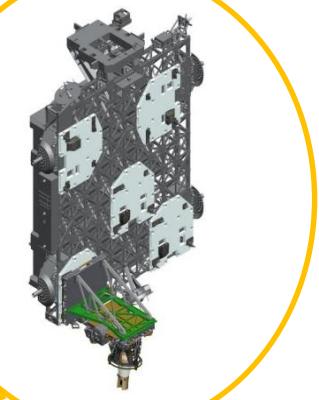
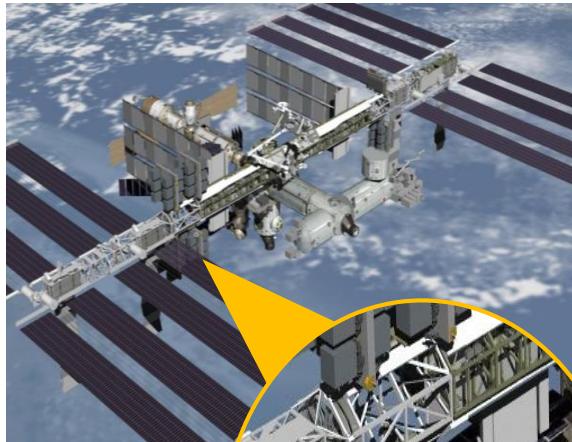


Dragon and ISS Configuration

Dragon Unpressurized Cargo Module



S3 Truss Payload Attachment System-4 Site
(PAS-4)



Passive FRAM Adapter
Plate Site 3 (PFAP-3)

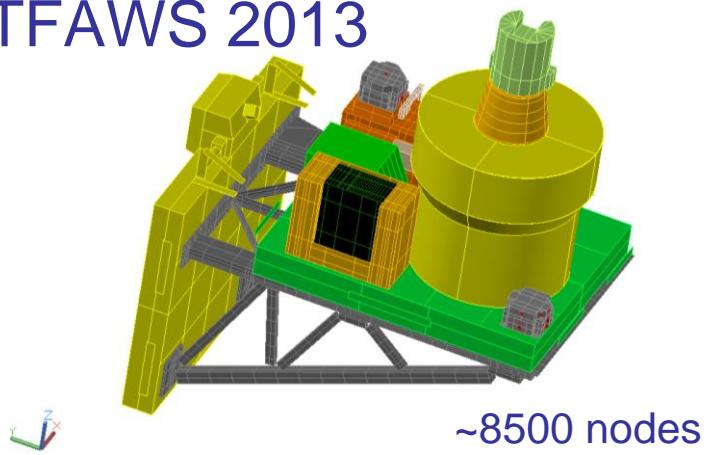


ExPRESS Logistics Carrier-4
(ELC-4)



Model Development Background

- Developed in Thermal Desktop® beginning in 2011
- Includes ISS and Dragon capsule
- Shared between several NASA engineers, contractors, and Italian payload partners
- Versioned: Current version 55f
 - Number represents major model change (number of nodes, save file no longer valid), letter represents minor tweak
- Initial development of efficient modeling methods was presented at TFAWS 2013





Inclusion of TVAC Chambers and GSE

- SAGE III thermal vacuum (TVAC) testing has occurred in two chambers at NASA LaRC
 - 6'x6' chamber has 3 independently-controlled temperature zones (GN₂-controlled shroud and two LN₂/heater controlled platens)
 - 8'x15' chamber has an LN2-controlled shroud and quartz lamps separated into 6 zones
- Representations of each chamber have been included in the system-level model (same model with ISS)
 - 6'x6' model includes two platens and a node to represent the shroud temperature
 - 8'x15' model includes an accurate representation of the full chamber geometry
- SAGE III Ground Support Equipment (GSE), primarily heater plates, has also been included in each chamber model



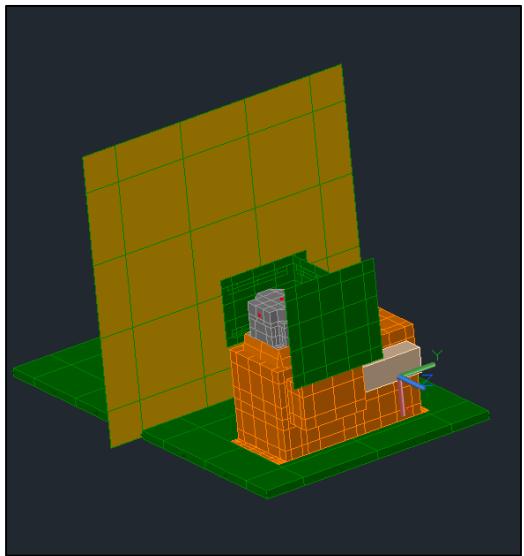
Method

- Chambers are turned on/off using flags
- 8'x15' chamber position is adjusted to match the positioning in the chamber only for cases where that chamber is on
 - Symbols were created for X/Y/Z translation and rotation, controlled via logic (i.e., $(\text{Flag_IP_Tvac} == 1) ? 90:0$)
- Symbols are used to set zone temperatures
- In addition to chamber controls, SAGE III utilizes heater plates to achieve subsystem temperature targets
 - Heater plate GSE is included in the chamber models and turned on/off using the same flags

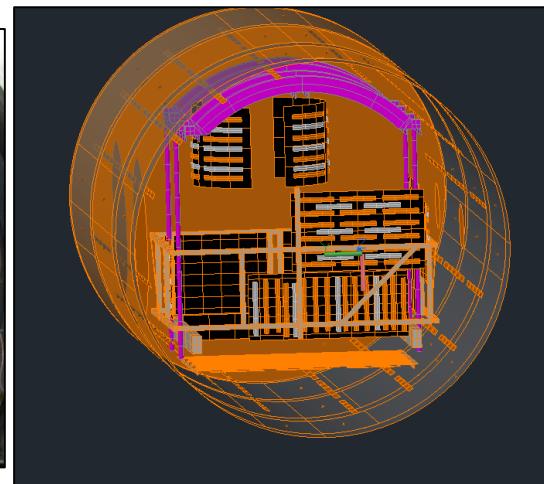
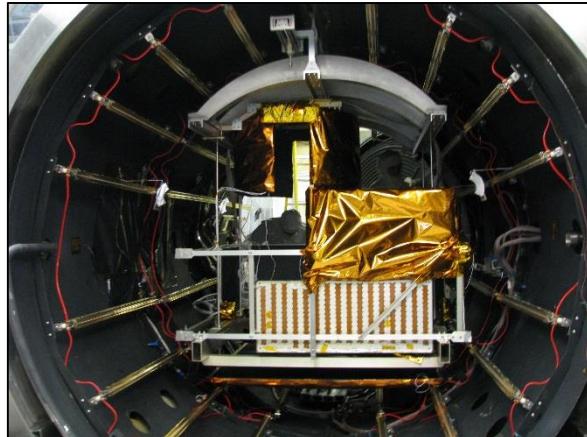
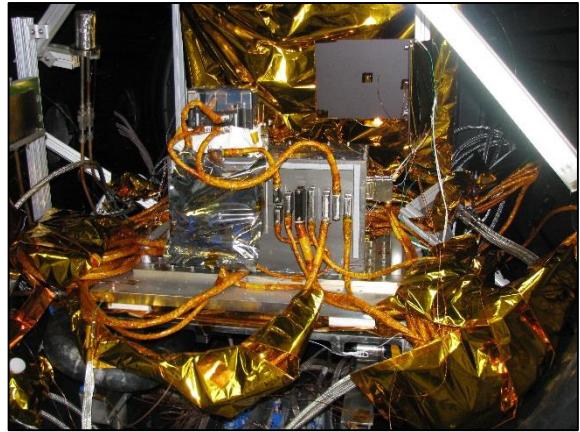
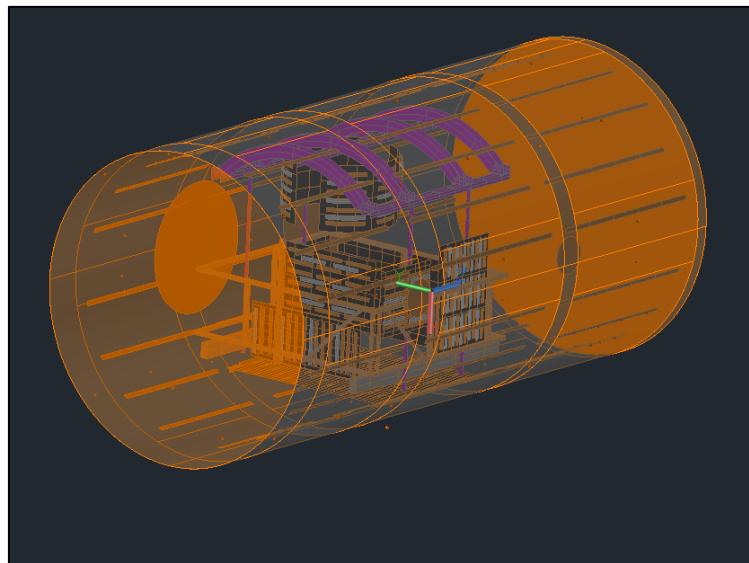


Photos and Model Images

6' x 6' Chamber



8'x15' Chamber





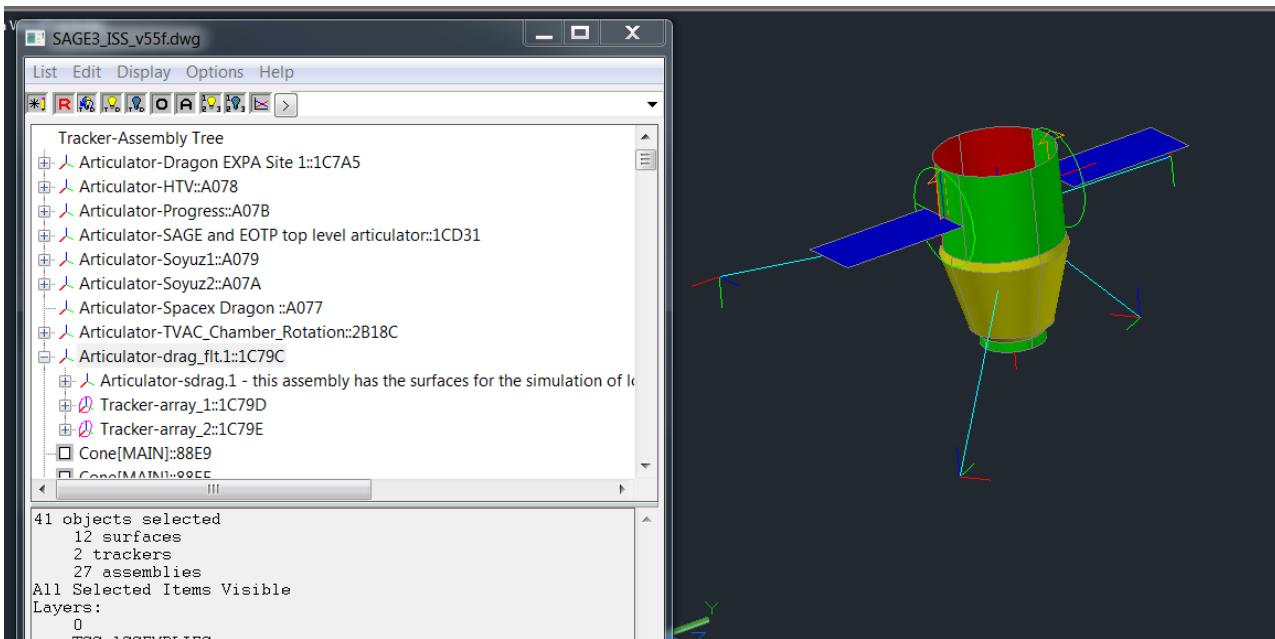
Benefits

- Accurate pre-test predictions are useful for verifying that targets can be achieved and estimating test time
- Having the chamber models in place prior to testing expedites correlation of the model to TVAC test data
- Including the chambers in the system-level model, rather than creating TVAC-specific versions, prevents the TVAC model from falling behind when the system-level model is updated
- Chamber models can be shared with future payloads



Use of Assemblies for Dragon Model Updates

- Orbit in the Dragon model v3r1 are substantially different from those defined in v2r1
- Assemblies were used to change the orientation of the Dragon, IP, and NVP submodels
 - Prevents having to re-orient the SAGE III model in a fixed way
 - Allows for easy incorporation of future Dragon orbits

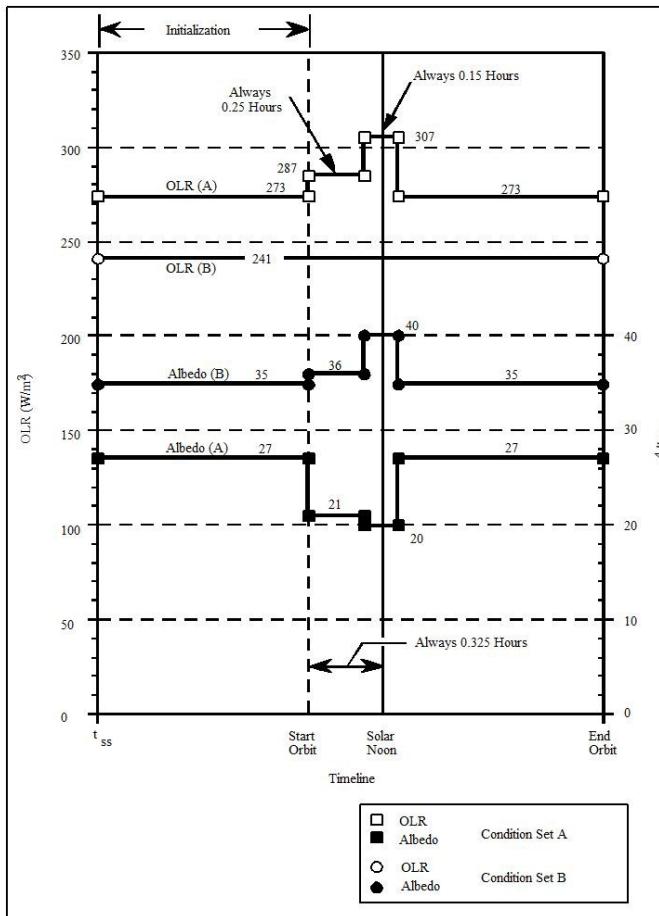




Creation of Time-Varying Orbital Parameters

- Per ISS requirements, SAGE III implemented time-varying orbital parameters (albedo and Earth IR)
 - First time this has been done in a payload developer's thermal model

**Example of Time-Varying
Parameters from SSP 57003-
ELC Rev D**





Method

- Arrays were created to represent the timeline and changing values for both parameters in each of the ISS-defined cases
 - ISS defines “A” and “B” cases for hot and cold, also broken down into “nominal” and “extreme” cases
- The interp function was used to create symbols for each parameter (albedo and Earth IR) for each of the ISS-defined cases
 - Ex: `interp(albedo_times_hot,albedo_values_hot_extreme_B,hrTime)`
 - A total of 8 timelines was created for each parameter
- Code has been made available to all NASA Centers on the Agency-wide share drive

Name	Result	Expression	Comment
albedo_times_cold	array	0.00125.251.4.401hrPeriod	times in hours for albedo values, design
albedo_times_hot	array	0.00125.251.4.401hrPeriod	times in hours for albedo values, design
albedo_time_varying_cold_A	0.27	interp(albedo_times_cold.albedo_values_cold_A,hrTime)	albedo in design cold A as function of time
albedo_time_varying_cold_B	0.22	interp(albedo_times_cold.albedo_values_cold_B,hrTime)	albedo in design cold B as function of time
albedo_time_varying_cold_extreme_A	0.27	interp(albedo_times_cold.albedo_values_cold_extreme_A,hrTime)	albedo in extreme cold A as function of time
albedo_time_varying_cold_extreme_B	0.2	interp(albedo_times_cold.albedo_values_cold_extreme_B,hrTime)	albedo in extreme cold B as function of time
albedo_time_varying_hot_A	0.27	interp(albedo_times_hot.albedo_values_hot_A,hrTime)	albedo in design hot A as function of time
albedo_time_varying_hot_B	0.35	interp(albedo_times_hot.albedo_values_hot_B,hrTime)	albedo in design hot B as function of time
albedo_time_varying_hot_extreme_A	0.3	interp(albedo_times_hot.albedo_values_hot_extreme_A,hrTime)	albedo in extreme hot A as function of time
albedo_time_varying_hot_extreme_B	0.4	interp(albedo_times_hot.albedo_values_hot_extreme_B,hrTime)	albedo in extreme hot B as function of time
albedo_values_cold_A	array	270.0.27.27.27	albedo values, design cold A case, from
albedo_values_cold_B	array	220.0.22.22.22	albedo values, design cold B case, from
albedo_values_cold_extreme_A	array	270.0.27.27.27	albedo values, extreme cold A case, from
albedo_values_cold_extreme_B	array	200.0.20.20.20	albedo values, extreme cold B case, from
albedo_values_hot_A	array	27.21.21.20.20.27	albedo values, design hot A case, from
albedo_values_hot_B	array	.35.36.36.40.40.35	albedo values, design hot B case, from
albedo_values_hot_extreme_A	array	30.25.25.25.30.30	albedo values, extreme hot A case, from
albedo_values_hot_extreme_B	array	40.45.45.53.53.40.40	albedo values, extreme hot B case, from
OLR_time_varying_cold_A	217	interp(albedo_times_cold.OLR_values_cold_A,hrTime)	OLR in design cold A as function of time
OLR_time_varying_cold_B	241	interp(albedo_times_cold.OLR_values_cold_B,hrTime)	OLR in design cold B as function of time
OLR_time_varying_cold_extreme_A	206	interp(albedo_times_cold.OLR_values_cold_extreme_A,hrTime)	OLR in extreme cold A as function of time
OLR_time_varying_cold_extreme_B	241	interp(albedo_times_cold.OLR_values_cold_extreme_B,hrTime)	OLR in extreme cold B as function of time
OLR_time_varying_hot_A	273	interp(albedo_times_hot.OLR_values_hot_A,hrTime)	OLR in design hot A as function of time
OLR_time_varying_hot_B	241	interp(albedo_times_hot.OLR_values_hot_B,hrTime)	OLR in design hot B as function of time



Setting Model Parameters with Case Definition

- Model includes a small set of registers that fully control case definition
 - Parameters such as initial temperature, heater voltage, power dissipation
 - Type of case such as payload location, flight scenario (science event type), TVAC case (balance or functional), special scenarios (plume heating, parked ISS trackers, etc.)
- Flags are used in case sets, logic blocks, and enable blocks to set up the desired scenarios
 - Case_def (values 0, 1, 2, and 3) is used to represent cold, nominal and hot cases; controls boundary conditions and component power dissipations
 - Flag_NVP_MOV and Flag_SAGE_MOV are used to define the position of the payload (Dragon, EOTP, ELC)
 - Flag_voltage sets voltage to minimum or nominal
 - Flag_IP_TVAC and Flag_TVAC_6x6 are used to specify TVAC cases
 - Flag_survival and Flag_transfer are used to define scenarios with survival heater power only or no power during transfer from one location to another
 - Flag_plume_heat and Flag_park_port_SARG define special scenarios
- Allows many different scenarios to be run by simply defining a few flags in the case set



Examples of Case Definition

Flight Hot Op Case on ELC

Override List		
Symbol	Override	Global
Case_def	2	1
Flag_NVP_MOV	0	0
Flag_SAGE_MOV	0	0
NumOrbits	15	20
rot_scan_head	300	0

Flight Cold Survival Case on EOTP

Override List		
Symbol	Override	Global
Case_def	0	1
case_SITE	1	0
Flag_NVP_MOV	2	0
Flag_SAGE_MOV	2	0
flag_survival	1	0
NumOrbits	15	20
switch_EOTP_DOE	1	0

IP TVAC Case

Override List		
Symbol	Override	Global
flag_IP_TVAC	1	0
flag_main_output_file_set	0	1
Flag_NVP_MOV	1	0
flag_QFLOW	0	1
flag_Tshrouds_uniform	1	0
Gflux_coupled	1000	250
t_end	40	48
T_shroud_rings	-180	-140
T_TVAC_CMP1_plate	92	20
T_TVAC_CMP1Z_plate	92	20
T_TVAC_CMP2_plate	111	20
T_TVAC_ExPA_plate	82	20
T_TVAC_HEU_plate	57	20
T_TVAC_IAM_plate	-150	20
T_TVAC_ICE_plate	32	20
T_TVAC_SA_plate	40	20

Logic Based on Case Definition Flags

Enabled...

Comment: Set parameters based on case: cold/survival/transfer/nominal/standby/startup

Submodel: (GLOBAL)

Code placed in: Operations Block Post Build (TDPOSTBL)

Declarations (COMMON blocks, INTEGER, REAL):

```
C Power values are in W (converted to Btu/hr in array data blocks)
C Boundary temperatures converted from C to F (KKL, 1/13/12), back to C in v27 10-30-12

C Hot case block
  IF (Case_def.GT.0) THEN
    T_TEC_cold_side = 15.
  ENDIF

C Cold case block
  IF (Case_def.EQ.0) THEN
    fac_power = 0.9
    Q_flex_cable_housing = 0.0
    T_TEC_cold_side = 10.
  ENDIF

C Electronics box powers in cold case
C CMP1 powers in cold op case
C fac_Q_CMP1 added so that total CMP power will be 3.25W, measured idle value (KKL, 3/6/14)
  fac_Q_CMP1 = 0.525
  Q_CMP1_DCDC_U1_U2 = 0.75
  Q_CMP1_DCDC_U8 = 0.75
  Q_CMP1_DCDC_U2A = 0.54
  Q_CMP1_FPGA = 0.615
  Q_CMP1_MSFT = 0.0
  Q_CMP1_TQCM = 0.0
  Q_CMP1_ANLG = 1.4875
  Q_CMP1_MAIN = 0.9645
  Q_CMP1_POWER = 0.33

C CMP2 powers in cold op case
C Changed to DCDC powers to hot case values because cold powers listed were higher than hot case (KKL 2/1/13)
C fac_Q_CMP2 added so that total CMP power will be 3.25W, measured idle value (KKL, 3/6/14)
  fac_Q_CMP2 = 0.571
  Q_CMP2_DCDC_U1_U2 = 0.56
  Q_CMP2_DCDC_U8 = 0.643
  Q_CMP2_DCDC_U2A = 0.54
  Q_CMP2_FPGA = 0.615
```



Incorporation of Convection Submodel

- Addition of a convection submodel that is only built for certain cases has proved useful for several situations
 - Submodel includes air nodes and convection conductors which are not built for flight cases; activated by flags
- One component underwent testing in both air and vacuum
 - Incorporating air convection allowed for correlation of all cases to occur in a single model
- Following completion of payload integration, several functional tests were completed in a clean room environment
 - Incorporating air convection allowed for early quick-look correlation work to be completed prior to TVAC testing
- Air convection model was used to show that the EMI setup with the payload bagged would not result in limit exceedences



Approach for Case Grouping

- The current SAGE III system-level model contains ~250 cases
- Run directories are defined by model version, payload location, and hot/cold case (i.e. v55_runs\ELC_hot, v55_runs\EOTP_cold)
 - Keeps the cases organized in a way that's easy for multiple users to understand
- Each group of cases has a common run directory
 - Makes it easy to update the run directories when the model version is changed
 - Minimizes the necessity to re-run radk cases for new analysis runs
- TVAC cases are grouped separately from flight cases





Summary

- Methods developed have made SAGE III analysis quicker, more accurate, and more flexible
- Up-front time investment has paid off in faster analyses
- Methods shared with other programs and Centers
- Other payloads, particularly ISS and Dragon, may find these methods useful



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